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Effect of Technology-Based Programs on First- and Second-Grade Reading Achievement

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Effect of Technology-Based Programs on First- and Second-Grade Reading Achievement

ABSTRACT. Data gathered from 25 rural public school districts in Texas during 2002-2003 were used to assess the impact of educator professional development and technology-intensive classroom learning activities on first- and second-grade students' reading achievement. Students from 18 school districts received the treatment while students from 7 randomly selected districts matching the treatment demographic criteria served as controls. Major findings were that the program was effective in fostering reading accuracy at the first- and second-grade levels and reading comprehension at the second-grade level. Effect sizes (ES) for identified areas of impact among treatment versus comparison sites were in the range of ES = .19 to ES = .65, meaningful values which are reinforced by alternative measures of significant ($p < .05$) impact. These findings compare favorably with previously published studies of similar, successful educational interventions involving technology and reading. doi:10.1300/J025v24n03_03

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KEYWORDS. Technology, professional development, reading achievement, technology integration measures

Data for the research reported in this paper were gathered as part of a five-year, large-scale technology innovation project funded by the federal government of the United States. A brief description of the project is provided initially, in order to give context to the study.

PROJECT OVERVIEW

The Key Instructional Design Strategies (KIDS) project was one of 14 Technology Innovation Challenge Grants awarded for 1999-2004 by the United States Department of Education. Fifty Texas school districts were involved by year five of the project. The KIDS model for technology-intensive education was refined in a large public school district in a northern suburb of Dallas, during the first year of the project. Transferability of the model was demonstrated in a largely Hispanic suburban district near the border of Texas and Mexico, and for a geographically remote, small rural district, during year two. KIDS project resources and activities were then introduced to rural school districts across Texas in years three to five through a series of intensive summer professional development institutes, through hardware/software resources allocated directly to local districts, and through technology-intensive services featuring a Lightspan-developed, Internet-delivered, Early Reading Center for K-3 students. Initial activities were documented in a series of books that reported the effectiveness of the project's professional development activities on technology integration gains for teachers (Knezek & Christensen, 2000; Christensen & Knezek, 2001; Knezek & Christensen, 2002).

TECHNOLOGY AND READING FOCUS

Beginning in 2002 the KIDS project was refocused on K-3 reading. Since a pre-post annual test was already required for all Texas students at this level, an opportunity arose to conduct scientifically based research on the impact of KIDS project activities as an educational intervention. Seven randomly selected control districts matching the KIDS project selection criteria were chosen to compare with 18 treatment districts joining the project in 2002. Teachers in treatment districts received summer

institute training in activities such as personal Web page development, electronic portfolios, online quizzes, digitizing curriculum, and other techniques to integrate technology into the classroom, in addition to the new technology-based reading program. All treatment districts received access to the Early Reading Center beginning with the summer institute in 2002, and none had received significant exposure to the Early Reading Center for their students as of May 2002. Although there were numerous outcomes from multiple facets of the project, the impact of this technology-based intervention on reading achievement is the focus of this paper.

LITERATURE REVIEW

Researchers have known for decades that technology can help improve reading. Soe, Koki, and Chang (2000) reviewed 17 studies spanning 1992-1999 and found in all cases effect sizes were positive for the impact of computer-assisted instruction (CAI) on K-12 reading achievement. Blok, Oostdam, Otter, and Overmatt (2002) conducted a meta-analysis of 47 1990-2000 studies and found an average effect size of .2 for Dutch and .5 for English CAI instruction in support of reading. Schacter (2001), in a study conducted for the nonprofit Milken Family Foundation, identified approximately one dozen technology-based reading programs with research on effectiveness and showed that several had strong evidence of success. Several previous studies have shown positive impacts of technology-intensive programs on reading. The unique contribution of the current study is the focus on the acquisition of reading skills at the first- and second-grade levels.

METHODOLOGY

Research Design

Scientifically based research principles complying with the spirit of the No Child Left Behind Act (U.S. Department of Education, 2002) were followed in developing the design for this study. The U.S. Institute of Education Sciences guidelines for strong evidence of effectiveness include:

1. The intervention should be demonstrated effective, through well-designed randomized controlled trials, in more than one site of implementation;

2. These sites should be typical school or community settings, such as public school classrooms taught by regular teachers; and
3. The trials should demonstrate the intervention's effectiveness in school settings similar to yours, before you can be confident it will work in your schools/classrooms (U.S. Department of Education, 2003, p. 10).

It is believed that the currently reported study of the impact of technology-intensive reading instruction on achievement complied with all three criteria listed above. The primary independent (intervention) variable was whether classrooms of students received access to the Early Reading Center, while the primary dependent variable (outcome measure) was reading achievement. The students in this study represented a cross-section of the population.

Description of the Intervention

Professional development for teachers, access to hardware/software resources, and use of the Early Reading Center modules are all considered part of the educational intervention in this study. During each of the summers of the project, five full days of educator professional development included a variety of hands-on workshops taught by experienced classroom teachers who had been integrating technology into their classrooms. How to use technology that these districts could purchase with their grant money ($40,000 per district in addition to the Early Reading Center access) was the focus of the majority of the workshops in the portion of the summer activities attended by one or more of the five-member training team from each district. Classroom teachers attending the reading institute portion of the summer activities spent much of their time learning the many facets of the Early Reading Center. At the end of the five days, the five district team members met and decided what technology-related items to purchase based on what they had learned and experienced during the week. Prior to leaving the Institute, each district wrote a plan of action for how they would integrate technology. This team then returned to their home school district to train fellow educators in the implementation of the Early Reading Center as well as the other technology-enhanced tools for teaching and learning that were introduced at the Institute.

Staff members from the KIDS project visited the schools during the year to provide support. One summer institute participant from each district was designated to be the district contact person. This person kept the

KIDS project staff abreast of developments in their district. In addition, the KIDS project team created newsletters that were distributed to all project participants.

Areas addressed in the Early Reading Center were oral language development, awareness of sound, symbol, and structure, skill integration reading comprehension strategies, vocabulary, spelling and writing. Students completed various high-interest technology-based reading modules. While the Early Reading Center was newly developed in conjunction with this project for children through third grade, there were also other Lightspan and non-Lightspan products that students in this project were able to access. For example, Achieve Now is a Lightspan product that allows access at home to learning modules in mathematics and reading/language arts, and Accelerated Reader is a reading-level-matching and reward incentive program used by many schools. Detailed descriptions of reading programs used by sizeable subsets of teachers in the KIDS project are provided in *Scientifically-Based Research on Technology and Reading Achievement: KIDS Project Findings for 2002-2003* (Knezek & Christensen, 2003, pp. 37-58).

Selection of Subjects

Assignment to treatment and control groups was based on randomized selection of control subjects from the pool of Texas school districts matching the following treatment criteria:

1. At least 42% of students eligible for free or reduced lunches,
2. Student population of 1,000 or fewer, and
3. Rated at a category below "Recognized" by the Texas Education Agency (TEA) at the time of admission to the KIDS Project.

The selection was carried out using consecutive entries from a random number table to match numeric labels for eligible districts.

INSTRUMENTATION

Reading Achievement Measures

The Texas Primary Reading Inventory (TPRI) is an early diagnostic assessment individually administered by the classroom teacher. As of

2002, over 90% of Texas school districts and charter schools were using the TPRI (Texas Education Agency, 2002). Because of this widespread usage, the TPRI was chosen as the primary instrument for assessing individual student reading achievement in this study. Forty of 41 districts in the KIDS grant were already using this assessment tool at the time it was selected for KIDS project research.

The TPRI was designed to be administered in kindergarten, grade one, and grade two. For grades one and two, the assessment incorporates phonemic awareness, word reading, reading fluency, and reading comprehension. Due to the low number of kindergarten teachers participating in the KIDS grant, only first- and second-grade TPRI data were included in this study. A separate analysis of the TPRI (Knezek, Christensen, & Dunn-Rankin, 2003) confirmed that it had acceptable measurement properties for the areas reported in this paper.

TPRI Testing Procedure

When tested with the TPRI, each student was asked to read an assigned story aloud to the teacher. The teacher had a copy of the story in the student record sheet and marked with a slash [/] any words that were not read correct including mispronunciations, substitutions, omissions, reversals, and hesitations longer than three seconds. The reading accuracy level (RAL) was then determined by what percentage of the total words in the story were miscalled (marked with a slash). Each student was rated at the *frustrational* level if she/he scored below 90%, *instructional* level if she/he read with an accuracy of 90%-94%, and *independent* level if reading accuracy was 95% or above. An additional reading accuracy level was created by the research team for students who were assigned and able to read a story above their grade level. Specifically, if the student was able to read the above-grade-level story at an *instructional* or *independent* level, she/he was rated *exceptional* by the evaluators. Each reading accuracy level (RAL) was then assigned a value from zero to three, with zero for *frustrational*, one for *instructional*, two for *independent*, and three for *exceptional*.

Classroom Reading Level Index

Since the classroom was selected as one of the major units of analysis for the KIDS project activities, a weighted average procedure was adopted to assign a single reading level number to an entire class of students.

Reading accuracy level numbers (0-3) were totaled and divided by the total number of students in the class. Thus an average for the entire class was created that could then be compared to other classes or to the same class at a different time, in a pre-post fashion.

Preliminary validation studies for this index indicated that it functioned well at the first-grade level but suffered from a ceiling effect at grade two. This was due to the fact that the TPRI itself had no way to designate the reading level of a student who read beyond the highest story level at grade two, and, hence, for second-graders, there was no logical means for assigning a rating of "3" to a second-grade student's reading ability. Because of this limitation, second-grade findings presented in this paper often do not include Classroom Reading Level Index (CRLI) data.

Data Acquisition and Coding

TPRI data were gathered by mailing TPRI forms to the participating KIDS districts requesting that each classroom teacher or district representative fill in the children's scores on the provided form. Raw scores were requested as opposed to a check mark under the heading of *developed* (meaning that the student had mastered the skill) or the heading of *still developing* (which implied that the student had not yet mastered the skill). A form with an example of how to complete it was provided. Completed forms were hand entered into a spreadsheet by a reading specialist based on a coding scheme previously established by the researchers. Data were then analyzed using the Statistical Package for the Social Sciences (SPSS, 1999).

All 18 2002-2003 treatment school districts, plus 7 randomly selected control districts were asked to submit TPRI data that they gathered from their K-2 students. The TPRI pretest (beginning of year) was administered throughout these rural school districts in September-October 2002, and posttest (end of year) was administered in April-May 2003. Regarding the pretest, completed forms from 40 classrooms in 22 districts were received from first-grade teachers; whereas 41 completed forms came from second-grade teachers. On the posttest, 33 completed forms were received from first-grade teachers, and 33 completed forms were received from second-grade-teachers. Pretest and posttest data were aligned manually, matching 434 first-grade students, and 453 second-grade students. Complete prepost data allowed approximately 70% of these records to be included in the analyses producing the results described in the following sections.

FINDINGS

Results for First-Grade Analysis

As shown in Table 1, KIDS project first-grade classrooms gained significantly ($p < .05$) more than control group first-grade classrooms in the areas of whole classroom reading level (CRLI), word lists, reading accuracy, and story level. These are all believed to be indicators of word reading ability. Also shown in Table 1 is that neither of the two reading comprehension indicators (*explicit questions* and *implicit questions*) were found to have significantly greater gains for treatment than for control students at the first-grade level. These results collectively indicate that KIDS project activities were successful in promoting gains in word reading ability in the treatment schools. For reading comprehension at the first-grade level there appeared to be no significant differences between treatment and control groups.

Results for Second-Grade Analysis

As shown in Table 2, reading accuracy (RA) gain was significantly greater ($p = .007$) for treatment students at the second-grade level. This

TABLE 1. TPRI First-Grade Reading Gain Statistics, Treatment versus Control

Measure	Treatment/ Control	*n*	Mean	*SD*	*T*	*df*	One-Tail Sig.	Effect Size
Classroom	Treatment	288	1.23	.36	5.68	387	.0005	.65
Reading Index	Control	101	.98	.39				
WORDGAIN	Treatment	210	4.87	2.33	2.11	202	.018	.25
	Control	100	4.29	2.24				
RAGAIN	Treatment	203	1.23	.84	4.06	189	.0005	.50
	Control	99	.80	.87				
LEVLGAIN	Treatment	177	.86	.65	1.89	250	.03	.23
	Control	93	.73	.45				
EQGAIN	Treatment	238	.47	1.01	.52	260	.30	.05
	Control	119	.42	.91				
IQGAIN	Treatment	238	.32	.89	.90	288	.19	.10
	Control	118	.24	.70				

Note. Effect size = (mean of treatment–mean of control/pooled *SD*)

TABLE 2. TPRI Second-Grade Reading Gain Statistics, Treatment versus Control

Measure	Treatment/ Control	*n*	Mean	*SD*	*T*	*df*	One-Tail Sig.	Effect Size of KIDS
Classroom	Treatment	264	.61	.30	1.71	381	.044	.19
Reading Index	Control	119	.56	.15				
RAGAIN	Treatment	207	.59	.668	2.49	255	.007	.38
	Control	50	.34	.52				
EQGAIN	Treatment	242	.56	1.02	1.73	310	.042	.23
	Control	70	.33	.90				
IQGAIN	Treatment	242	.51	.86	1.77	310	.039	.24
	Control	70	.30	.95				

index from the TPRI is a measure of word reading ability. CRLI gains were significantly greater ($p < .05$) for second-grade treatment students as well.

At the second-grade level, participation in the KIDS project also resulted in significantly ($p < .05$) greater gains in reading comprehension as measured by explicit and implicit questions on the TPRI. In both measures of comprehension (EQGAIN and IQGAIN), the treatment students were higher than the control students in their gains.

Comparison of Findings for Grade One and Grade Two

Reading accuracy gains shown in Table 2 for second-grade students are similar to first-grade reading accuracy gains shown in Table 1. For both grade levels, treatment students gained more ($p < .05$) than controls. In the area of comprehension gains, however, at the second-grade level the treatment students were higher than controls, but at the first-grade level no significant differences between treatment and control gains were found.

Examination of Relative Gains

While the analyses presented in Tables 1 and 2 were based on treatment versus control gain scores, in this section we present raw score means and standard deviations for each group at the pretest and posttest

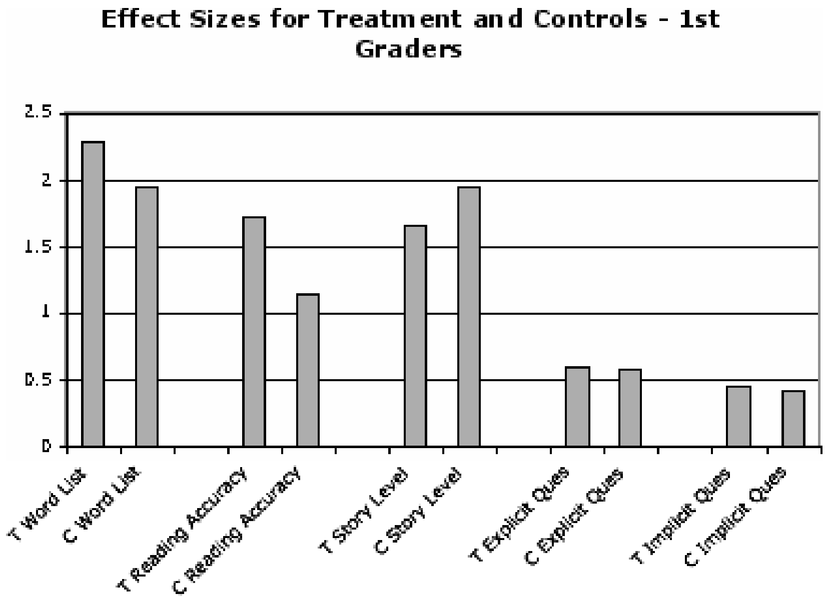
time frames. The pairs of effect sizes reported in Tables 3 and 4 represent: (1) the impact of the technology-enhanced treatment, next to (2) the impact of typical classroom (control group) reading instruction. Note that both the treatment and control interventions resulted in learning improvements in the range of moderate (ES = .5) to very large (ES > .8) effects of instruction, according to guidelines provided by Cohen (1969). However, in all but one case, the impact of the technology-enhanced instruction, as indicated by the magnitude of the pre-post effect size, was greater for the technology-intensive reading program than for the control group.

As shown in Table 3 and Figure 1, the relative magnitude of pre-post effect sizes for treatment versus control groups on the variable *story level* are in opposite directions from their relative mean gains and should be interpreted with caution due to non-normality in this data (Coe, 2000). All other differences in indices, including the classroom reading level index (not shown), are in the conjectured direction, although for explicit and implicit questions, the differences between treatment and control are very small (not statistically significant). Note that the differences between the treatment group and control group effect sizes for reading comprehension gains during the first grade are very close to zero for both *explicit question* and *implicit question* measures, even though gains in reading comprehension for both groups had effect sizes in the range of .41 to .59, indicating meaningful educational progress (ES ≥ .3) (Bialo & Sivin-Kachala, 1996). This reiterates the finding from the previous section,

TABLE 3. Comparison of Pre-Post Reading Gains for First-Grade Treatment Group versus First-Grade Control Group

TPRI Indicator	Treatment/ Control	Pretest		Posttest		*N*	Effect Size
		Means	*SD*	Means	*SD*		
Word Lists	Treatment	1.39	2.28	6.26	1.99	210	2.28
	Control	1.99	2.53	6.28	1.84	100	1.94
Reading Accuracy	Treatment	.74	.83	1.85	.38	122	1.72
	Control	1.04	.91	1.84	.40	99	1.14
Story Level	Treatment	1.06	.26	1.92	.69	177	1.65
	Control	1.03	.18	1.76	.50	93	1.94
Explicit Questions	Treatment	2.09	.90	2.57	.71	238	.59
	Control	2.21	.79	2.63	.66	119	.58
Implicit Questions	Treatment	1.24	.73	1.55	.63	238	.45
	Control	1.46	.59	1.69	.53	118	.41

FIGURE 1. Effect size comparison for first-grade treatment and control groups on TPRI indicators.



that while the KIDS project activities were effective in fostering higher overall reading achievement than the control group activities for grade one, there is no evidence that this applies to reading comprehension specifically at grade one.

As shown in Table 4 and graphically displayed in Figure 2, analyses of pre-post effect sizes at the second-grade level reconfirm the findings reported in Table 2. That is, reading improvements were greater for both reading accuracy and reading comprehension among classrooms from the KIDS treatment districts. For *reading accuracy*, *explicit questions* and *implicit questions*, each treatment versus control comparison is in favor of the KIDS treatment by a sizeable margin.

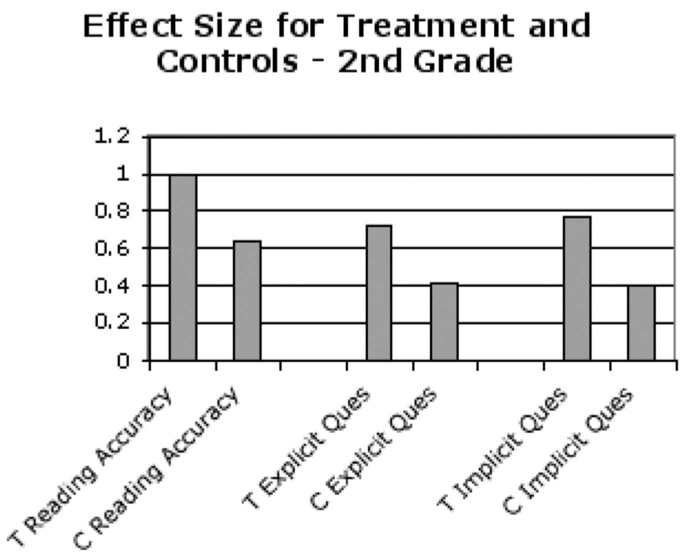
DISCUSSION

The plan for use of treatment and control groups is a rigorous research design that approaches a true experimental design as defined by

TABLE 4. Comparison of Pre-Post Reading Gains for Second-Grade Treatment Group versus Second-Grade Control Group

TPRI Indicator	Treatment/ Control	Pretest		Posttest		*N*	Effect Size
		Means	*SD*	Means	*SD*		
Reading Accuracy	Treatment	1.25	.78	1.85	.36	207	.99
	Control	1.46	.61	1.80	.45	50	.63
Explicit Questions	Treatment	2.05	.91	2.62	.65	242	.72
	Control	2.19	.87	2.51	.68	70	.41
Implicit Questions	Treatment	1.08	.76	1.60	.59	242	.76
	Control	1.09	.76	1.39	.73	70	.40

FIGURE 2. Effect size comparison for second-grade treatment and control groups on TPRI indicators.



scholars in the field of educational research such as Campbell and Stanley (1963). True experiments, which require that any subject (a student in a school) have an equal opportunity to be randomly selected for treatment or control group, are very difficult to achieve in educational environments. In this study, entire districts of students were randomly selected as members of the control group. It is believed that there are

no serious threats to internal validity in the approach, and the major threat to external validity should become a delimitation of the study. That is, the findings of this experiment can only be assumed to be valid for school districts matching the profile of those selected for KIDS participation.

There is often controversy among researchers about the best way to analyze pre-post treatment versus control data. For example, Gall, Gall and Borg (2003, pp. 427-428), have pointed out that gain scores like those used in most analyses for this study have potential problems such as ceiling effects, regression toward the mean, and low reliability. However, analysis of covariance (with pretest scores as covariates), which is the most widely recommended alternative to analysis of gain scores, also has limitations. Particularly controversial is the use of ANCOVA when its assumptions are not met. These assumptions include normality of the mean distribution, equal variance for the pretest (covariate), homogeneity of regression between the pretest and posttest (the slopes of treatment and control groups should be the same), the absence of outliers, and a highly reliable covariate (Tabachnick & Fidell, 2001, pp. 390-394). An examination of the data in this study during a comparison of three analysis techniques revealed the assumption of homogeneity of regression, for analysis of covariance was violated in eight of nine analyses in which it was employed. A separate analysis comparing *t*-tests on gain scores, analysis of covariance, and repeated measures analysis of variance concluded:

> In terms of the comparison of the different tests to yield statistically significant results, the *t*-test on pre-post gain scores appears to be the most powerful, yielding most of the control-treatment comparisons as significantly different (all except *explicit questions* and *implicit questions* for grade one). Another statistical procedure yielding statistically significant differences across multiple measures (CRLI and *reading accuracy* for both grade levels) was ANOVA for repeated measures. These statistical procedures appear to be the most sensitive to the gains achieved by individual students or classes of students during the school year. Both types of procedures would appear to be intuitively appropriate for assessing the accomplishments by a classroom teacher during the school year at the first- or second-grade level, since both take into account the level of the students when the year began. (Morales & Knezek, 2003, p. 174)

Proper unit of analysis is yet another issue commonly debated in educational research. In the context of this study, the issue is whether randomly selected control districts are simply sampling units to choose individual students who should be included in a student-as-unit-of-analysis study, or whether classrooms nested within schools are the smallest unit of analysis that can be treated as a coherent whole. Additional analyses based on multidimensional scaling methods (Dunn-Rankin, Knezek, Wallace, & Zhang, 2004) and reported elsewhere (Knezek & Christensen, 2003) have convinced the authors that the sampling technique appears to have been unbiased, the intervention was truly implemented on an 18-district rather than a classroom-by-classroom basis, and the most important measure is how much reading ability an individual student gained, not just her/his reading ability at the end of the school year. These determinations argue in favor of a within-student, pre-post analysis such as has been reported in many parts of this paper. Nevertheless, when summarizing findings from this study, we have elected to report the most conservative ($p < .05$) levels of significance for confirmed findings–those typically based on classroom-as-a-unit-of-analysis–in recognition of ongoing discussions in this area. Fortunately the use of effect size (APA, 2001) allows readers to judge for themselves whether a given impact was large enough to be considered educationally meaningful, and we have relied extensively on the use of this metric in this paper. Interpretations based on effect size will be returned to at the conclusion of this section.

Rationales for many findings from this study can be found in the published literature on the subject of reading. For example, among KIDS project classrooms at the first-grade level, most gains attributable to KIDS project participation were in the area of word reading ability. In *A Child Becomes a Reader, Kindergarten through Grade 3* (Armbruster, Lehr, & Osborn, 2003), expectations are that children will learn word identification skills in first grade. Though comprehension skills and strategies are introduced in kindergarten and first-grade, they are more fully developed and refined in second and third grades. Analysis of second-grade TPRI data revealed that word reading ability continued to be positively influenced by KIDS project initiatives at this level, but reading comprehension as measured by explicit and implicit questions also showed greater gain for the treatment group at the second-grade level. This outcome is consistent with published literature in this area. The ability to read words is a precursor to understanding what is read. Therefore, one would expect first-graders to be learning skills that will aid them in comprehending text at grade two and beyond.

A study by Wigfield and Guthrie (1997) found that boys and girls differed in their motivation to read, with girls generally showing more positive motivation for reading. Post-hoc examination of KIDS project first-grade student data by gender revealed that girls were higher in reading accuracy at the pretest ($f = 5.07$, 1×226 *df*, $p = .025$, ES = .29) as well as posttest ($f = 10.38$, 1×251 *df*, $p = .001$, ES = .40) measurement points for the first grade. However, analysis of pre-post gain scores yielded no significant ($p < .05$) differences for learning gains attributable to gender, and analysis of pre-post scores by gender within treatment and control disaggregated groups uncovered no evidence that the technology-intensive treatment was more effective for either boys or girls.

One unit of measurement for presenting findings throughout this paper is effect size, an index that places test scores on a common scale (for comparison to others) by presenting them in terms of standard deviation units. For at least three decades researchers have relied on effect size as a standard metric for comparing results across studies (Cohen, 1969; 1988). Effect sizes for several studies that had areas of focus similar to KIDS project activities are listed in Table 5. These range from .16 to .25, and, by comparison, place findings from the KIDS project in a favorable light.

TABLE 5. Effect Size for Studies Involving Technology and Beginning Reading Achievement

Study/Educational Intervention	Effect Size	Source
Computer-assisted instruction in support of beginning reading instruction: A review	0.19 ± 0.06	Blok, Oostdam, Otter, and Overmaat (2002)
Effectiveness of computer-based instruction: An updated analysis	0.25 ± 0.07	Kulik and Kulik (1991)
A meta-analysis: Effectiveness of computer-assisted instruction at the level of elementary education (K-6)	0.16 ± 0.08	Ouyang (1993)
KIDS project 2002-2003 Word Reading Accuracy (grades 1, 2)	0.50 grade 1 0.38 grade 2	Table 1, Table 2 (ES for Treatment vs. Control Gains)
KIDS project 2002-2003 Reading Comprehension (grades 1, 2)	0.08 grade 1 0.24 grade 2	Table 1, Table 2 (ES for Treatment vs. Control Gains)

Note. Explicit question (EQ) and *implicit question* (IQ) measures were averaged to produce a composite measure of reading comprehension.

Viewed from a slightly different perspective, the North Central Regional Educational Laboratory (NCREL, 2002) has reported that an effect size of 0.1 is equivalent to about one month of learning gain. If this holds true for reading acquisition at the first- and second-grade level, then the effect sizes for areas of statistically significant ($p < .05$) treatment group participation found in this study, which range from .19 to .65, imply that the added value of KIDS project participation is a gain of at least two months of additional progress by the learner, beyond the gain expected by the control group, over the course of one year. The average effect of the technology-intensive reading program implemented by the KIDS project, across all areas of positive impact reported for first-graders in Table 1 (ES = .23, .25, .50, .65) and second-graders in Table 2 (.19, .23, .24, .38), is ES = .33. The magnitude of this impact is in the range normally considered to be educationally meaningful according to established guidelines (Bialo & Sivin-Kachala, 1996).

CONSERVATIVE NATURE OF REPORTED EFFECT SIZE

Although Cohen's *d* ($(\text{mean}_1 - \text{mean}_2)$/pooled standard deviation) is a popular effect size statistic, researchers have pointed out others such as the Glass (1976) Statistic Delta ($(\text{mean}_{\text{Exp.}} - \text{mean}_{\text{Cont.}})/\text{standard deviation}_{\text{Cont.}}$) may be more appropriate (less conservative) in true experiments because the standard deviation of the randomly selected controls is the best representative of the unaltered population of subjects, and this standard deviation is typically smaller than the group that has been subjected to a treatment. For the KIDS data, computation of Glass's Delta for the values in Tables 1 and 2 did raise the estimate of the effect size of the technology-intensive reading program in most cases, the largest change being for classroom reading level index at grade two, where $ES_{\text{Delta}} = .33$ ((.61 − .56)/.15) versus the reported Cohen's *d* of .19. However, the average estimate of effect size across all significant ($p < .05$) measures was only increased slightly, to .37 for Glass's Delta versus .33 for Cohen's *d*. Therefore Cohen's *d* was retained as the reported index of effect, for ease of comparability to other findings, with the knowledge that the effects reported for the technology-intensive reading treatment may be somewhat conservative in this study.

The conservative nature of the findings reported in this paper extend one additional step to the reported measures of gain in Tables 3 and 4. Cohen (1988, pp. 48-49) showed that when pre-post matched pairs data

are used in computing effect size, the magnitude of the pre-post effect can be adjusted by dividing the normal Cohen's *d* value by the square root of (1-correlation of pre-post measure with itself), with higher correlation resulting in greater increase in the estimate of effect. Spot checks of available data for several indices showed that this adjustment could raise estimates of pre-post effect reported in Tables 3 and 4, but that the profiles of treatment versus control gains in Figures 1 and 2 would remain unchanged. For these reasons the computationally simpler Cohen's *d* was retained as an index of pre-post gain.

SUMMARY/CONCLUSIONS

Data gathered from 25 rural public school districts in Texas during 2002-2003 indicate that Key Instructional Design Strategies (KIDS) project professional development and technology-intensive classroom learning activities were effective in fostering reading accuracy at the first- and second-grade level and reading comprehension at the second-grade level. Effect sizes for identified areas of impact among treatment versus comparison sites were in the range of ES = .19 to ES = .65, meaningful values which are reinforced by alternative measures of significant ($p < .05$) impact and which compare favorably with previously published studies of similar, successful educational interventions.

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